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# ANALOG MODEL PREDICTION OF THE HYDROLOGIC EFFECTS OF SANITARY SEWERAGE IN SOUTHEAST NASSAU AND SOUTHWEST SUFFOLK COUNTIES, NEW YORK

By

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Dennis J. Sulam, Rufus T. Getzen

U. S. Department of the Interior
Geological Survey

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## CONVERSION FACTORS

Computer printouts from the U.S. Geological Survey electric analog model in Mineola, N.Y., show head changes in meters; contours plotted on maps in this report are in meters; and discussion of these data in the text is also in meters. All other data are reported in English units.

| SI[1/] units | Multiply by | To obtain English units |
|---|---|---|
| meters (m) | 3.281 | feet (ft) |

| English units | Multiply by | To obtain SI[1/] units |
|---|---|---|
| miles (mi) | 1.609 | kilometers (km) |
| feet (ft) | .3048 | meters (m) |
| square miles ($mi^2$) | 2.590 | square kilometers ($km^2$) |
| million gallons per day (Mgal/d) | .04381 | cubic meters per second ($m^3/s$) |

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1/ International system of units.

# ANALOG MODEL PREDICTION OF THE HYDROLOGIC EFFECTS OF SANITARY SEWERAGE IN SOUTHEAST NASSAU AND SOUTHWEST SUFFOLK COUNTIES, NEW YORK

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## ABSTRACT

The probable effects of sewerage on ground-water levels in southeast Nassau County and southwest Suffolk County were predicted through use of an electric analog model of the greater part of the Long Island ground-water system. By 1995, 20 years after the start of sewerage in Nassau County, the predicted maximum water-level decline due to loss of recharge from individual domestic waste-disposal systems was a little more than 5 meters (16 feet) for both the upper glacial aquifer and the underlying Magothy aquifer. The greatest water-level decline was just south of the present ground-water divide, and aggregate average annual streamflow at the mouths of streams in the study area decreased by 60 percent.

Simulation of planned sewerage in southwestern Suffolk County from 1975 to 1995 indicated a decline of 1.5 meters (5 feet) in the water table and a decline of as much as 1 meter (3 feet) in potentiometric head in the Magothy aquifer. Simulation of planned sewerage in Suffolk and Nassau Counties combined caused a decline of as much as 6 meters (20 feet) in the water table and 5 meters (16 feet) in head in the Magothy aquifer, and a 40-percent decrease in streamflow in and around the area of sewerage.

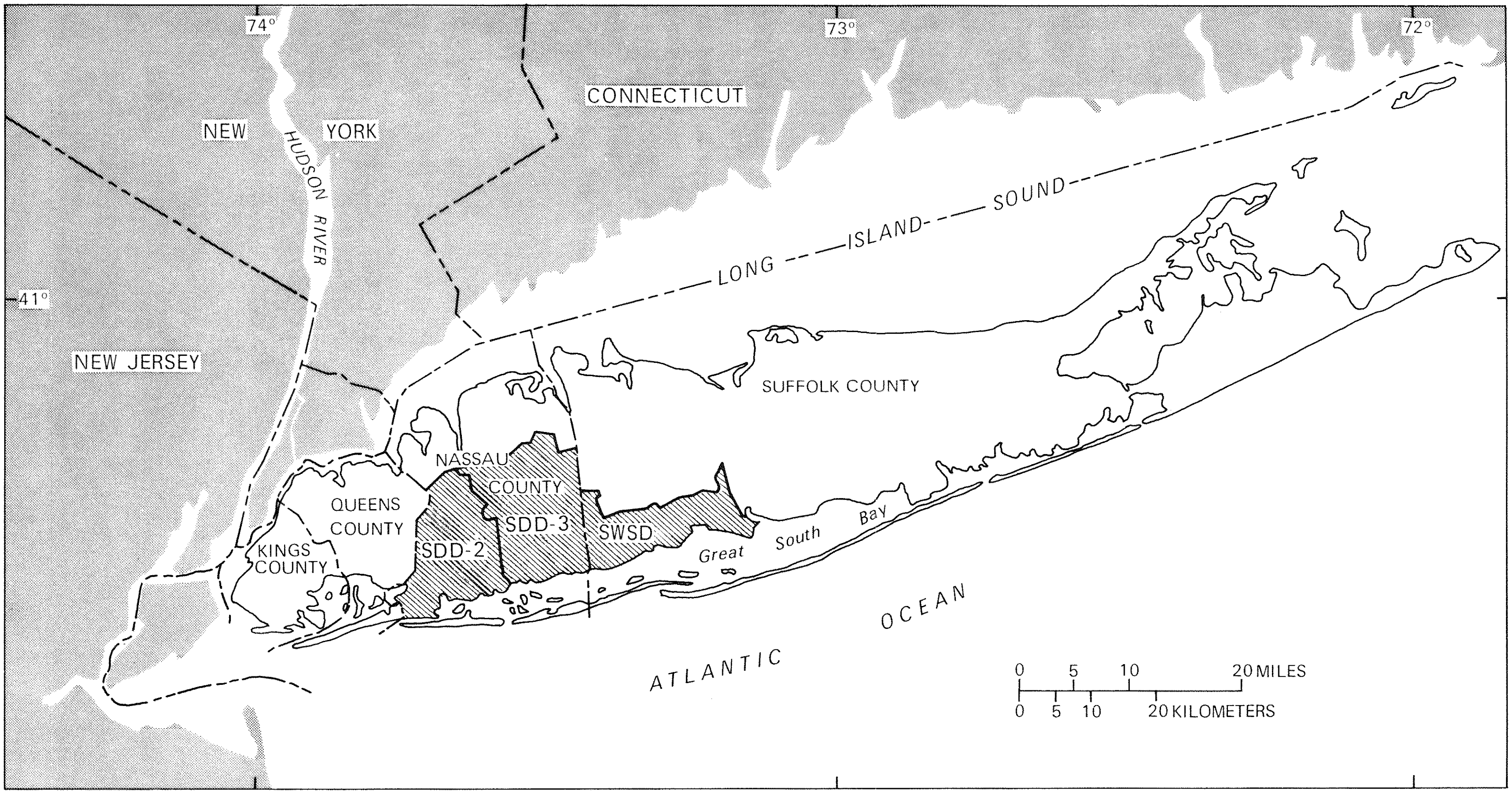



Figure 1.--Location of Nassau County Sewage Disposal Districts 2 and 3 (SDD-2 and SDD-3) and Suffolk County Southwest Sewer District (SWSD).

## INTRODUCTION

Ground water is the source of public water supply in Nassau and Suffolk Counties on Long Island (fig. 1). This water supply is recharged by precipitation that percolates to the water table. Since the 1950's, when extensive sewerage construction began in Nassau County, water managers and the interested public have been concerned with the effect that sewerage would have on the altitude of the water table.

The widespread use of domestic waste disposal systems--septic tanks and cesspools--for wastewater disposal on Long Island formerly allowed most of the water to be returned to the aquifer. However, this began to contaminate the groundwater and, although the introduction of sewerage may result in an improvement in ground-water quality by preventing waste from entering the aquifer, it also prevents replenishment of the ground-water reservoir. As sewerage continues to be expanded, the loss of recharge will lower the water table.

The general effect of sewerage is shown by a comparison of the amounts of withdrawal of public-supply water in areas with and without sewers. In 1972, public-supply pumpage in Nassau County was 174 Mgal/d (7.62 $m^3/s$) (New York State Department of Environmental Conservation, 1973). Sewer outflow that year from Nassau County Sewage Disposal District 2, which covers about one-fourth of the county (fig. 1), was 68 Mgal/d (3.0 $m^3/s$). This discharge, which was about 40 percent of the total 1972 Nassau County public-supply pumping, caused a decline in water levels (Franke, 1968; Garber and Sulam, 1976). An additional 67 Mgal/d (2.9 $m^3/s$) was pumped that year from aquifers underlying that part of Queens County adjacent to Nassau County--an area that had been fully sewered for decades--and the water table is currently (1976) below sea level in south-central Queens County.

In contrast, 1972 public-supply pumping in Suffolk County was 116 Mgal/d (5.08 $m^3/s$) (New York State Department of Environmental Conservation, 1973). Most of this withdrawal was in the western, heavily populated part of the County, where domestic waste-disposal systems are still in wide use, and no significant lowering of the water table has occurred there (Kimmel, 1971; Koszalka, 1975). Thus, the combined effect of pumping and discharge of sewage offshore can have significant effect on the ground-water reservoir.

The hydrogeologic environment on Long Island is particularly well suited to disposal through cesspools and septic tanks because of the permeable character of most of the surficial deposits. Domestic waste-disposal systems have caused some deterioration of ground-water quality, though, and this poses a potential threat to public water supplies in both Suffolk and Nassau Counties. For this reason, the counties have built or extended sewer systems in heavily populated areas. With the completion of the Bay Park Sewage Treatment Plant in 1953, Sewage Disposal District 2[1/],

1/ For the remainder of this report, Sewage Disposal Districts 2 and 3 in Nassau County, and Southwest Sewer District in Suffolk County will be referred to as SDD-2, SDD-3, and SWSD, respectively.

in the western part of Nassau County (fig. 1), began operation. Virtually the entire district was hooked up to the sewage-treatment facility by 1964. Sewer construction is also planned or underway in Sewage Disposal District 3 (SDD-3) in Nassau County and in the Southwest Sewer District (SWSD) in Suffolk County (fig. 1).

The major observable effects of sewerage are the decline of ground-water levels and the reduction of stream discharge and stream length. Salinity in south-shore bays also is affected by decreases in loss of streamflow and ground-water outflow. These two components collectively discharge to the bays an unknown but substantial part of the water that recharges the aquifer. The 66-Mgal/d (2.9-$m^3$/s) decrease in recharge from SDD-3 due to sewerage, calculated from pumpage estimated for 1985, and the estimated 30-Mgal/d (1.3-$m^3$/s) decrease from SWSD calculated from the 1985 sewage-treatment plant capacity, will produce a lowering of water levels and a reduction in streamflow.

The purpose of this report is to describe and predict the effects of sewerage on water levels and streamflow in southern Nassau and south-western Suffolk Counties. Predictions are based on results of tests run on the electric analog model of the Long Island hydrologic system. The stresses resulting from sewerage in SDD-3 and SWSD were modeled both separately and together. The assumptions and data used in modeling the effects of sewerage for SDD-3 and for SWSD were developed by H. F. H. Ku, R. T. Getzen, D. J. Sulam, and A. W. Harbaugh. The assumptions and data used to model the combined effects of sewerage in these districts were the result of a separate effort, and the section of the report that describes the effects of this combination is modified from a report by Kimmel and Harbaugh (1975).

## Hydrogeology

The hydrogeology of Long Island has been described in many earlier reports. The study area has been described in detail by Perlmutter and Geraghty (1963); Pluhowski and Kantrowitz (1964); and Ku, Vecchioli, and Cerrillo (1975). A generalized discussion of Long Island's hydrogeology is presented by Cohen, Franke, and Foxworthy (1968) and McClymonds and Franke (1972).

Long Island is underlain by a wedge of unconsolidated sedimentary deposits. The bedrock surface that underlies it dips southeast from near sea level in northwest Queens County to 2,000 ft (610 m) below sea level in parts of Suffolk County's south shore. Unconsolidated deposits of Cretaceous age, which also dip southeast, are mantled nearly everywhere on Long Island by Quaternary glacial deposits. A generalized description of Long Island's aquifer system is given in table 1.

Long Island has many streams, most of which are relatively short--15 mi (24 km) or less (fig. 2). Approximately 90 percent of the flow in these streams is derived from ground water; the amount of flow depends on the elevation of the water table. When the water table declines, the position of the start of flow in streams can move downstream; also ground-water gradients to the streams are generally reduced. Thus, the effect of a decline in the water table is a decrease in streamflow and stream length. Prior to urban development, about 60 percent of the water infiltrating the aquifer was discharged to streams (Franke and McClymonds, 1972, table 11). The dependency of streamflow on altitude of the water table is a significant factor in any model of Long Island's hydrologic system.

Table 1.--Generalized description of hydrogeologic units underlying study area 1/

| Hydrogeologic unit | Lithology and water-bearing character |
| --- | --- |
| Upper glacial aquifer | Mainly sand and gravel of moderate to high permeability; also includes clayey deposits of till of low permeability. |
| Gardiners Clay | Clay, silty clay, and a little fine sand of low to very low permeability. |
| Jameco aquifer | Mainly medium to coarse sand of moderate to high permeability. |
| Magothy aquifer | Coarse to fine sand of moderate permeability; locally contains gravel of high permeability and abundant silt and clay of low to very low permeability. |
| Raritan clay | Clay of very low permeability; some silt and fine sand of low permeability. |
| Lloyd aquifer | Sand and gravel of moderate permeability; some clayey material of low permeability. |

1/ Adapted from Cohen, Franke, and Foxworthy (1968).

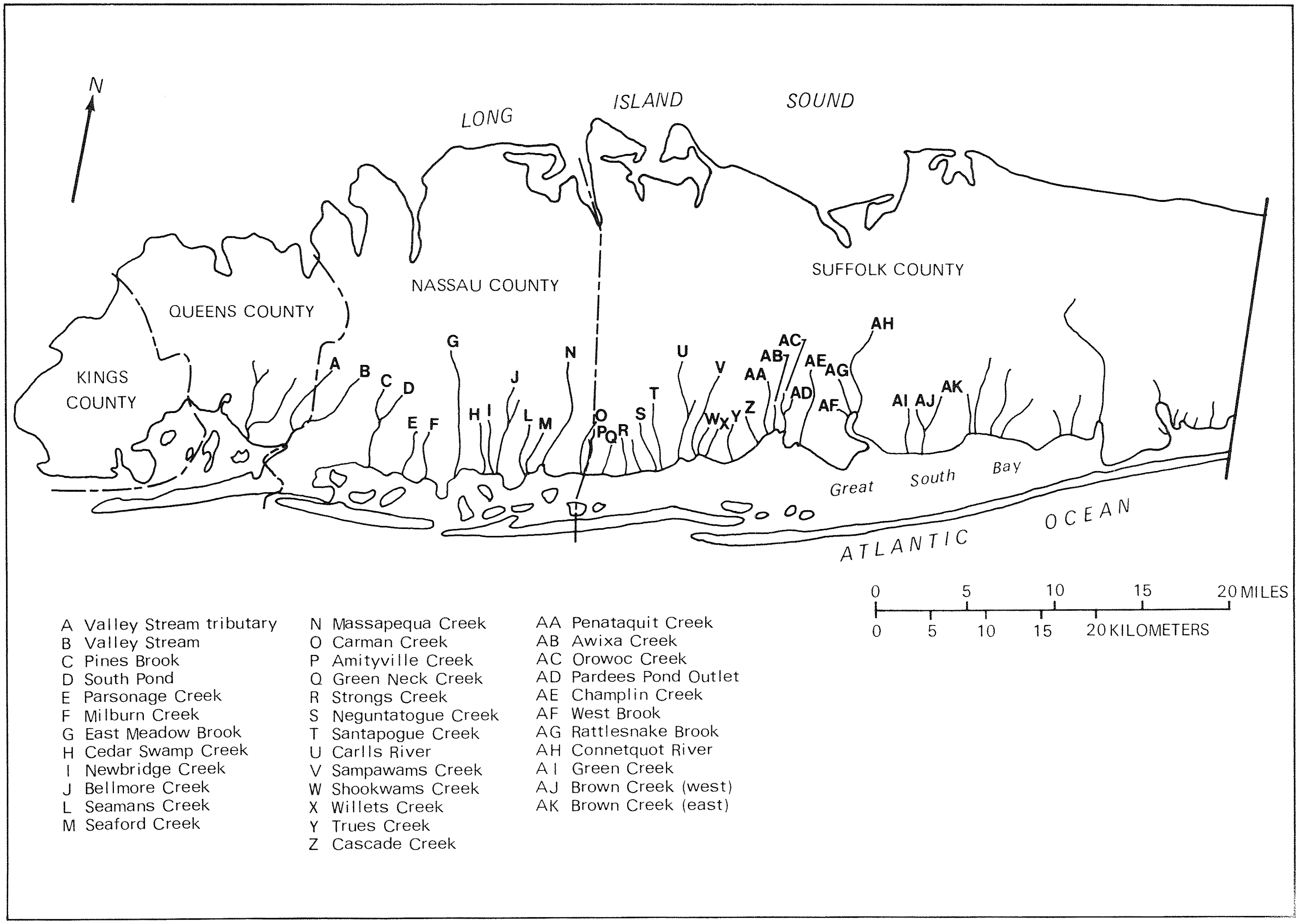



Figure 2.--Streams simulated in analog-model tests.

## Analog Model Simulation

The model used in this study is a three-dimensional electric-analog model that simulates the hydrogeology of the Long Island ground-water system to the base of the Magothy aquifer (Getzen, 1975). All of Long Island is represented in the model except for the eastern forks. The model consists of five layers that together simulate the upper two aquifers and associated confining beds. The upper glacial aquifer is represented by two layers, and the Magothy aquifer is represented by three layers. The Raritan clay and Lloyd aquifer were not included in these tests because their effect on water levels is minimal.

The model indicates changes in hydraulic head, through time, that would result from the input stress. Water-level changes can be demonstrated only on a regional basis because spacing between horizontal nodes represents the relatively large distance of 6,000 ft (1,830 m); therefore, changes in hydraulic head affecting less than half a node interval (3,000 ft or 915 m) are of little significance in the model. The model results from this study are intended to predict the effect of sewerage in broad areas of Nassau and Suffolk Counties at the end of the simulated period, 1975-95, but the reader is cautioned against using these data to predict hydrologic effects at any specific time or place.

The characterization of streamflow used in the initial model (Getzen, 1975) was modified in this study to improve the model's response to simulated stress (A. W. Harbaugh and R. T. Getzen, written commun., 1975). The numerous Long Island streams (fig. 2) were modeled in this study as gaining streams whose flow was proportional to elevation of the water table above the streambed. When the water level dropped below the streambed elevation at a given node, streamflow ceased at that node and at all points upstream from it. Thus, when flow ceased at a given node, model stream length was decreased accordingly.

Because of the model's relatively small scale, streams could not be simulated individually or in detail. For convenience, some of the streams were combined and represented by a single node or series of nodes. For example, the flows in streams I, J, and K (fig. 2) are treated as one flow in the model.

Streams on Long Island are gaged above tidewater, but streamflow on the model terminates at the mouth of the stream, which may be 1 mi (0.6 km) or more downstream from the gaging station. Streamflow in the model was first adjusted to the average annual streamflows obtained from gaging stations and was then modified to simulate the somewhat larger flow at the mouth. The gain in streamflow between gaging station and mouth was estimated by Getzen (1975) for each stream and incorporated in the model. Model streamflows are, therefore, average annual flows at the mouths of streams.

# ANALOG MODEL PREDICTION OF EFFECTS OF SEWERAGE IN SOUTHEAST NASSAU COUNTY

by

Henry F. H. Ku, Rufus T. Getzen, Dennis J. Sulam, and Arlen W. Harbaugh

The study area (fig. 1), SDD-3, encompasses 105 $mi^2$ (272 $km^2$) of mainly suburban residential communities. Because of increasing pollution problems caused by infiltration of cesspool and septic-tank effluent into the ground-water reservoir (Perlmutter and Koch, 1972) and also by the failure of cesspools and septic tanks resulting from age or the water table's being close to land surface, where domestic disposal systems do not work well, a program to replace individual waste-disposal systems with a public municipal sewer system was begun in SDD-3 in 1974.

The future impact of sewerage in SDD-3 on ground-water levels and streamflow in Nassau County was investigated by the electric-analog model technique. Sewerage in adjacent areas will have an additional effect on ground-water levels and streamflow in Nassau County, but, except for adjustment of model streamflow to 1975 conditions, past and future effects of other sewerage were not included in this analog-model simulation. SDD-2 has been in service for at least 10 years; thus, it was assumed that the effect of that sewer construction would have stabilized by the start of the study period. Suffolk County was not considered to have sewerage of sufficient magnitude to affect this analysis. The combined effect of sewerage in SDD-3 and projected Suffolk County sewerage is discussed in a later part of this report.

## Initial Hydrologic Conditions

In the absence of records and data, it was assumed at the outset that the water table in the upper glacial aquifer and the potentiometric surface for the Magothy aquifer were at steady state when sewerage was implemented (1975). This was probably a safe assumption because at present, pumped water is returned to the ground through cesspools and septic tanks. Neither the effects of pumpage and sewerage in adjacent areas, nor other factors that exist before and continue after introduction of sewerage, were modeled. Recharge from precipitation was also assumed to be constant and was so maintained throughout the simulations.

The flow of nine southward flowing streams in SDD-3 was simulated (fig. 2). The long-term average annual flow was used for gaged streams Bellmore and Massapequa Creeks (J and N, fig. 2), but for East Meadow Brook (G, fig. 2) and other streams to the west, the average flow for the period 1967-73 was used because recent annual discharges have been reduced to far below long-term average annual discharges.

Prior to the completion of sewers in SDD-3 in 1974, water pumped from the Magothy aquifer was returned to the upper glacial aquifer through septic tanks and cesspools. This recharge tends to increase storage in the upper glacial aquifer and makes additional water available to streams. In most of the study area, however, this increase was considered to be negligible because recharge to the upper glacial aquifer is offset by downward leakage into the Magothy. This leakage is induced by withdrawals from the Magothy and is facilitated by the good hydraulic connection between the two aquifers in this area.

## Stress on the Model

When sewers are installed, recharge that normally takes place through seepage of cesspool and septic-tank effluents is terminated, and the effluents are treated and discharged directly to tidewater. Because the quantity of water discharged approximates the quantity pumped for public supply, this pumping constitutes a major stress on the ground-water system.

Public-supply withdrawals in SDD-3 are grouped according to water districts, as shown in figure 3. Within a water district, users are more or less evenly spaced; hence the pumping stress was modeled uniformly throughout each water district.

Pumpage figures for 1970 were obtained from the New York State Department of Environmental Conservation (1973). It was assumed that the amount of water pumped from each water district was proportional to the population of that district. Population was estimated for the end of each 5-year period, beginning in 1970, on the basis of predicted population changes throughout the county (New York State Division of the Budget, 1973, table A-14). It was also assumed that per-capita use of water would generally remain constant throughout the study period. Table 2 gives the projected increase in population and pumpage for each water district. The data are arranged in order of the completion date of the proposed sewer construction (Nussbaumer, Clarke, and Velzy, 1964). It was also assumed that there would be no increase in population beyond the beginning of the sewered period; thus, for the whole area, there is no increase in withdrawal after 1985.

| Letter code | Water district |
|---|---|
| A | Massapequa and New York Water Service |
| B | East Meadow-Uniondale |
| C | Hicksville |
| D | Levittown |
| E | Farmingdale area |
| F | Bethpage |
| G | Plainview |
| H | Brookville-Jericho, Roslyn, and Old Westbury area |
| I | Carle Place |
| J | Westbury |

Note: Letter code correlates with that in table 2 and Figure 4

0 5 MILES
0 5 KILOMETERS

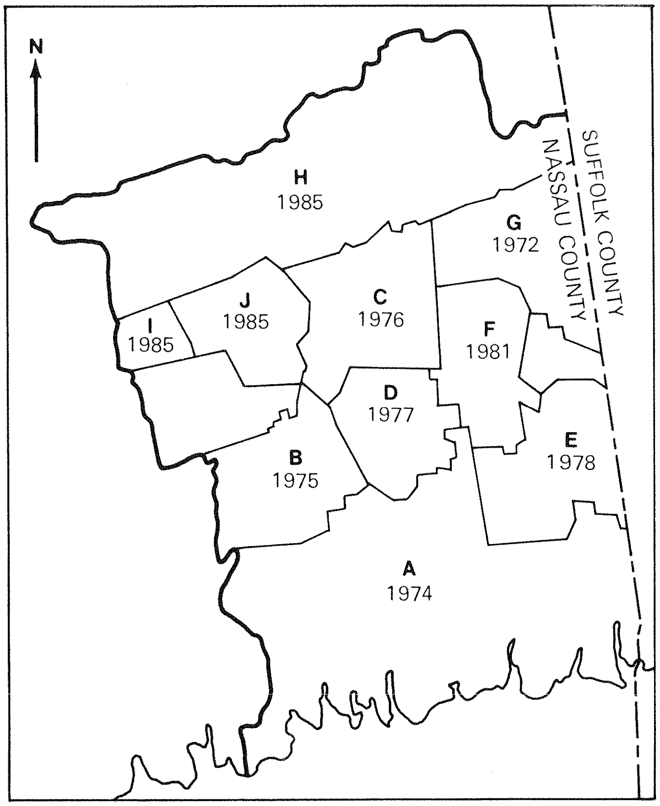



Figure 3.--Water districts and projected dates of sewer completion in Nassau County Sewage Disposal District 3.

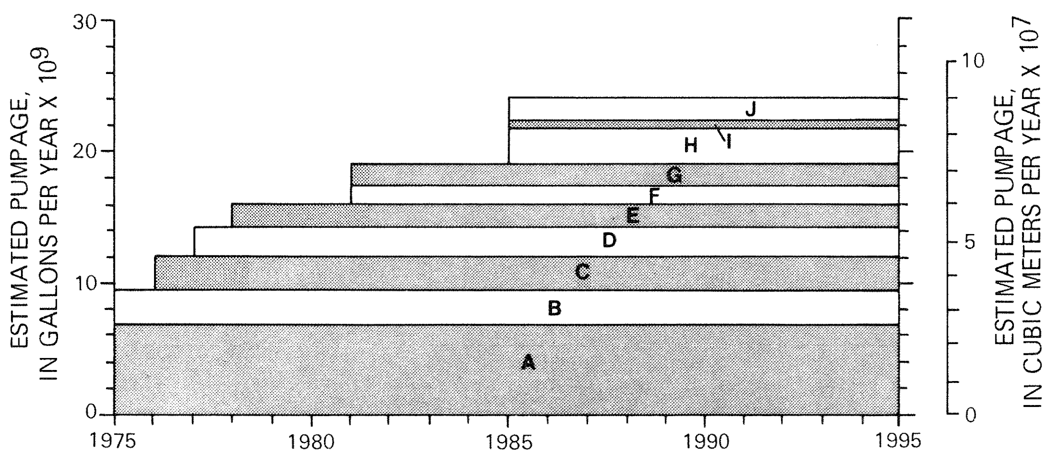
Table 2.--Projected population and pumpage in water districts affected by sewerage in Sewage Disposal District 3

[Population rounded to nearest 100; pumpage in billion gallons per year]

| Water district, with letter code used in figure 3 | 1970 | | 1975 | | 1980 | | 1985 | |
|---|---|---|---|---|---|---|---|---|
| | Population | Pumpage | Population (estimated) | Pumpage | Population (estimated) | Pumpage | Population (estimated) | Pumpage |
| A. Massapequa and New York Water Service | 217,000 | 6.109 | 222,900 | 6.276 | 232,000 | 6.533 | 240,800 | 6.781 |
| B. East Meadow-Uniondale | 75,000 | 2.535 | 77,100 | 2.605 | 80,200 | 2.711 | 83,200 | 2.814 |
| C. Hicksville | 55,000 | 2.323 | 56,500 | 2.387 | 58,800 | 2.485 | 61,000 | 2.579 |
| D. Levittown | 50,000 | 1.811 | 51,400 | 1.861 | 53,500 | 1.937 | 55,400 | 2.010 |
| E. Farmingdale area | 53,200 | 1.752 | 54,600 | 1.800 | 56,800 | 1.873 | 59,000 | 1.944 |
| F. Bethpage | 32,400 | 1.144 | 33,300 | 1.175 | 34,600 | 1.223 | 36,000 | 1.270 |
| G. Plainview | 40,000 | 1.632 | 41,100 | 1.676 | 42,800 | 1.745 | 44,400 | 1.811 |
| H. Brookville-Jericho, Roslyn, and Old Westbury area | 62,500 | 2.460 | 64,200 | 2.528 | 66,800 | 2.631 | 69,400 | 2.731 |
| I. Carle Place | 11,000 | .4524 | 11,300 | .4648 | 11,800 | .4838 | 12,200 | .5021 |
| J. Westbury | 35,500 | 1.496 | 36,500 | 1.537 | 38,000 | 1.600 | 39,400 | 1.661 |
| | | | | | | | Total withdrawal by 1985 | 24.103 |

Annual rates of withdrawal used in the simulations are given in figure 4, which is a simplified, graphical representation of the withdrawals simulated for the populations in table 2. Since population increase during the study period was small, it was assumed that the population would not increase once each district had been sewered and that withdrawal rates would, therefore, remain constant after installation of sewers. Total model withdrawal after 1985 was $2.4 \times 10^{10}$ gal/yr or 66 Mgal/d (2.9 $m^3/s$). Because stepped withdrawal rates were used, errors in model simulation occurred but disappeared within a year or two after initiation of the stress; therefore, the assumption that sewerage is instantaneous over each water district seems valid.

Consumptive use was simulated by withdrawing the respective amounts of water from the upper glacial aquifer simultaneously and at uniform rates in each water district. The amount withdrawn was the estimated amount of public supply at the time sewers were installed in the district, and this amount was continually applied until 1995, the end of the modeled period.




Letter code and water district

A Massapequa and New York Water Service
B East Meadow-Uniondale
C Hicksville
D Levittown
E Farmingdale area
F Bethpage
G Plainview
H Brookville-Jericho, Roslyn, and Old Westbury area
I Carle Place
J Westbury

Note: Letter code correlates with that in table 2 and figure 3

Figure 4.--Withdrawal scheme used in analog-model simulation for Nassau County Sewage Disposal District 3.

## Model Results

Net changes in head were computed for the upper glacial and the Magothy aquifers for the period 1975 to 1995 (figs. 5 and 6). Because sewer construction in SDD-3 is scheduled for completion by 1985 and no increased withdrawals were modeled after 1985, the net-change map for 1995 was assumed to represent a stabilized condition.

The maximum drawdown attributed to sewerage was a little more than 5 m (16 ft) for both the upper glacial and Magothy aquifers, with the greatest change 1 to 2 mi (1.6 to 3.2 km) south of the pre-stressed ground-water divide. The projected net change of 5 m (16 ft) agrees with the conclusions of Franke (1968) and Garber and Sulam (1976) for Sewage Disposal District 2, west of the study area. Net changes given in figures 5 and 6 reflect only the effect of sewerage in relation to the previously discussed, initial conditions.

The similarity between net-change configurations for the decline in water table (fig. 5) and decline in potentiometric head in the Magothy aquifer (fig. 6) supports the assumption of a good hydraulic connection between the two aquifers, which has been noted previously on Long Island (Kimmel, 1971). The Gardiners Clay is present only along the south shore of the study area, and therefore its effect as a confining unit is limited to offshore areas.

Several factors other than sewerage that may cause minor water-level changes were not modeled; these include climatic changes, changes in amount of impervious land surface in the area, changes in pumpage, and addition of sewerage in adjacent areas. Changes in water level attributed to sewerage can be superposed on the effects of other factors if these are known.

The greatest predicted water-level decline was just south of the pre-stressed ground-water divide (figs. 5 and 6), and this should cause the ground-water divide to shift northward. If the divide moves as expected, some of the ground water now flowing north from the divide will be reversed and will flow south in a small part of central Nassau County.

The declining water table in the upper glacial aquifer caused a corresponding reduction in streamflow. The aggregate decrease in discharge for streams in SDD-3 from 1975 to 1995 is shown in figure 7. By 1995, aggregate streamflow at the mouths of streams within SDD-3 decreased to 60 percent of the 1975 average annual flow, and this reduction was accompanied by a corresponding reduction in stream length. The amount of reduction in stream length could not be determined, though, because of the large area represented between each node (6,000 ft or 1,800 m) and the relatively short length of streams. Moreover, reduction in stream length is not directly proportional to the change in water-table altitude. Many factors in addition to sewerage, such as climatic changes and (or) local pumping and diversions, can cause changes in streamflow, as with water levels, but these were not simulated.

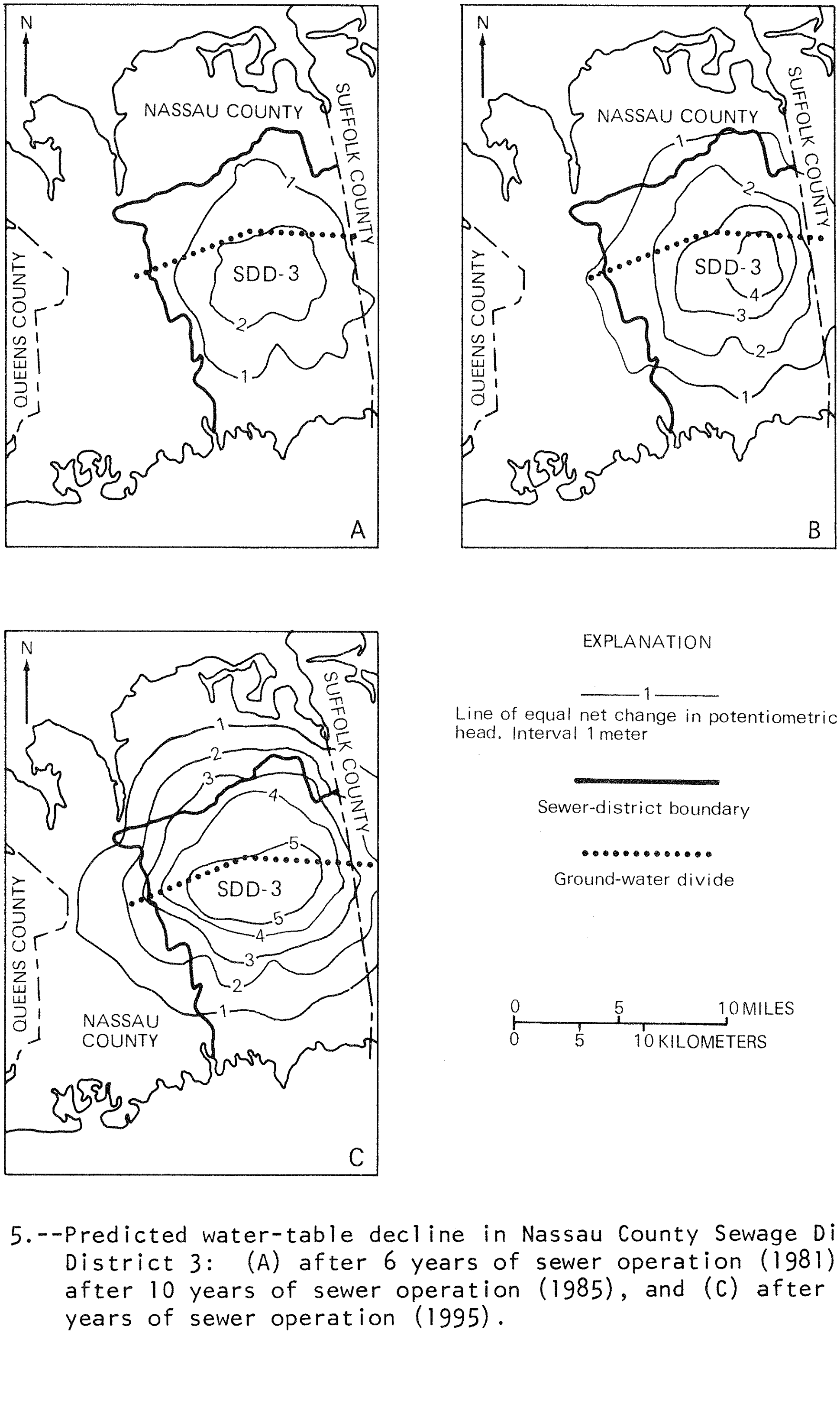



Figure 5.--Predicted water-table decline in Nassau County Sewage Disposal District 3: (A) after 6 years of sewer operation (1981), (B) after 10 years of sewer operation (1985), and (C) after 20 years of sewer operation (1995).

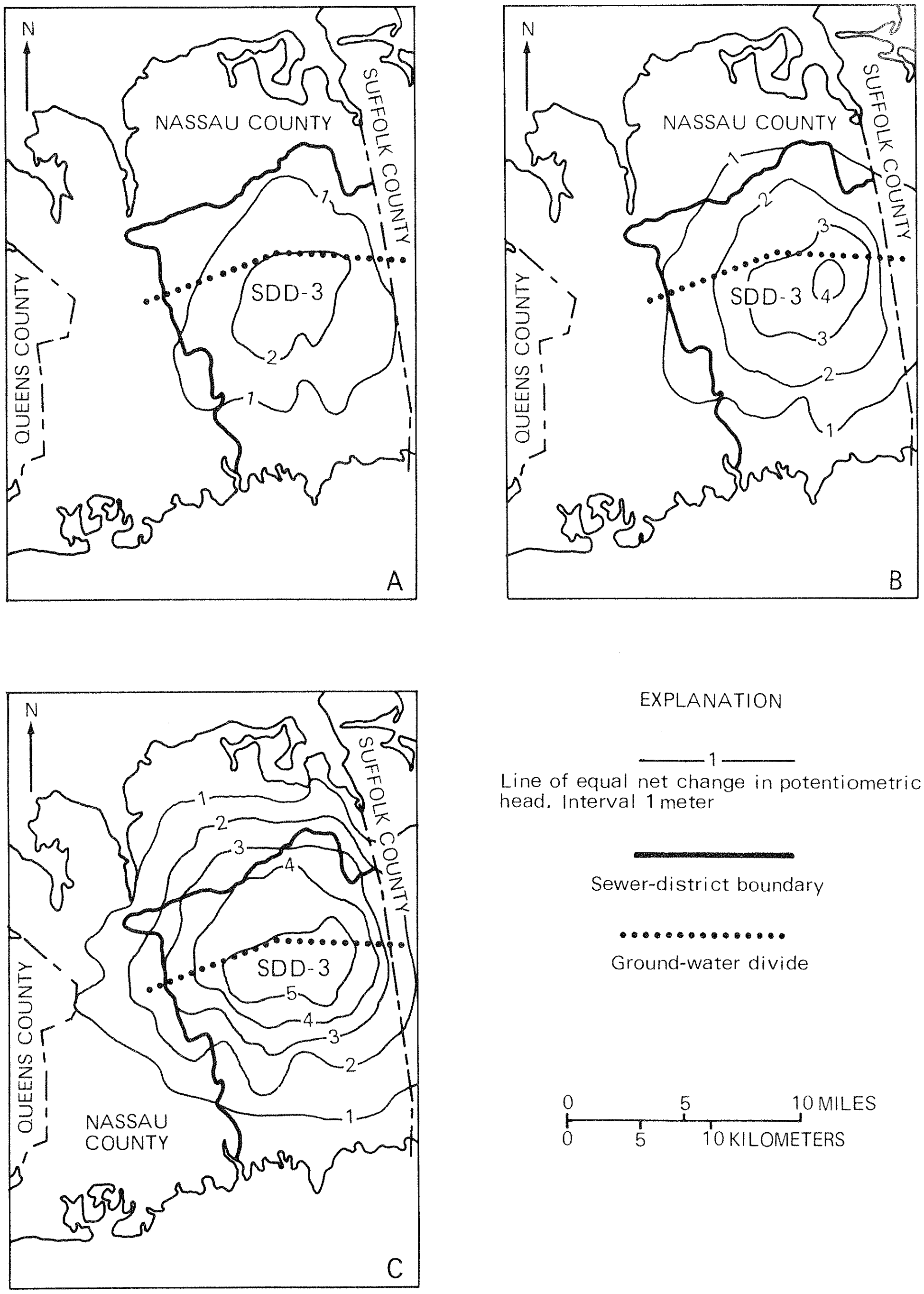



Figure 6.--Predicted decline in potentiometric head in Magothy aquifer, Nassau County Sewage Disposal District 3: (A) after 6 years of sewer operation (1981), (B) after 10 years of sewer operation (1985), and (C) after 20 years of sewer operation (1995).

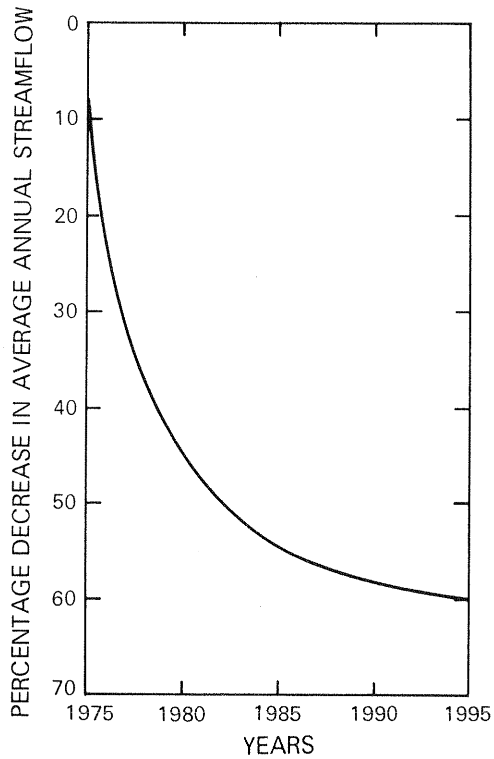



Figure 7.--Predicted aggregate average annual stream discharge resulting from sewerage in Nassau County Sewage Disposal District 3.

# ANALOG MODEL PREDICTION OF EFFECTS OF SEWERAGE IN SOUTHWEST SUFFOLK COUNTY ALONE AND IN COMBINATION WITH THAT IN SOUTHEAST NASSAU COUNTY

By

Grant E. Kimmel and Arlen W. Harbaugh

The construction of sewers in Suffolk County under the supervision of the Suffolk County Department of Environmental Control began in the SWSD (Southwest Sewer District) about 1970. This district comprises about 60 $mi^2$ (160 $km^2$) of the Towns of Babylon and Islip along the north shore of the Great South Bay (fig. 1). Sewer construction is expected to be completed by 1980, but, unlike Nassau County, in which certain sections of the sewer district will be connected to the sewage-treatment facility before the district is completed, SWSD will begin hookups throughout the district upon completion of the treatment facility. Hookups are expected to be complete by 1985, and the flow to the treatment facility at that time was estimated by the Suffolk County Department of Environmental Control to be 30 Mgal/d (1.3 $m^3/s$).

## Stress on the Model

Ground-water conditions before the period of modeling were assumed to be the same as those described in the previous section for southeast Nassau County. An increase in population of SWSD would increase withdrawals, but, because the population here was assumed to have stabilized before the beginning of the study period, water demand was assumed to have stabilized also. The only variable in the modeled system was reduced recharge as a result of sewerage.

Before sewerage, there was little consumptive use (loss) of water because most of the pumped water was returned to the upper glacial aquifer through cesspools. The withdrawal of water was simulated according to the proposed sewer-construction schedule. Calculations based on that schedule indicated that a maximum volume of 30 Mgal/d (1.3 $m^3/s$) of sewer effluent would be reached by 1985 and that this rate would continue through 1995, the end of the modeled period. In contrast, however, data presented by the Suffolk County Department of Environmental Control indicate that the volume of sewer effluent will increase at a somewhat variable rate. From 1980 to 1985, this rate can be approximated by a straight line when graphed (fig. 8).

In 1974, about 14 percent of Suffolk County pumpage was from the upper glacial aquifer and 86 percent was from the Magothy aquifer. Most of the pumpage from the Magothy and all the pumpage from the upper glacial aquifer was in the western part of SWSD. For the model studies, the sewer district was divided into halves, with 65 percent of the pumpage in the west half and 35 percent in the east half. The authors assumed that by 1980 and

beyond, all pumpage would be from the Magothy aquifer, and that because population will have stabilized, the distribution and rate of pumpage would be the same as in 1974. Because pumpage from the Magothy aquifer during the period 1974-95 was considered to be constant, it was not simulated, and only withdrawals from the upper glacial aquifer due to sewerage were modeled. The pumping stress was increased equally throughout the district at the rates given in figure 8. Magnitude of stress was distributed in proportion to the pumpage in the east and west halves of the district.

Because sewers are being constructed in Nassau and Suffolk Counties simultaneously, additional model analyses were made to predict the effects that the combined sewerage plans would have on Nassau County water levels. The assumptions and data used for SDD-3 were somewhat different from those used for SWSD: (1) in SWSD, the amount of sewer effluent was modeled as a net withdrawal; (2) SWSD was divided into two subdistricts, and the magnitude of stress due to sewerage was distributed uniformly on the basis of

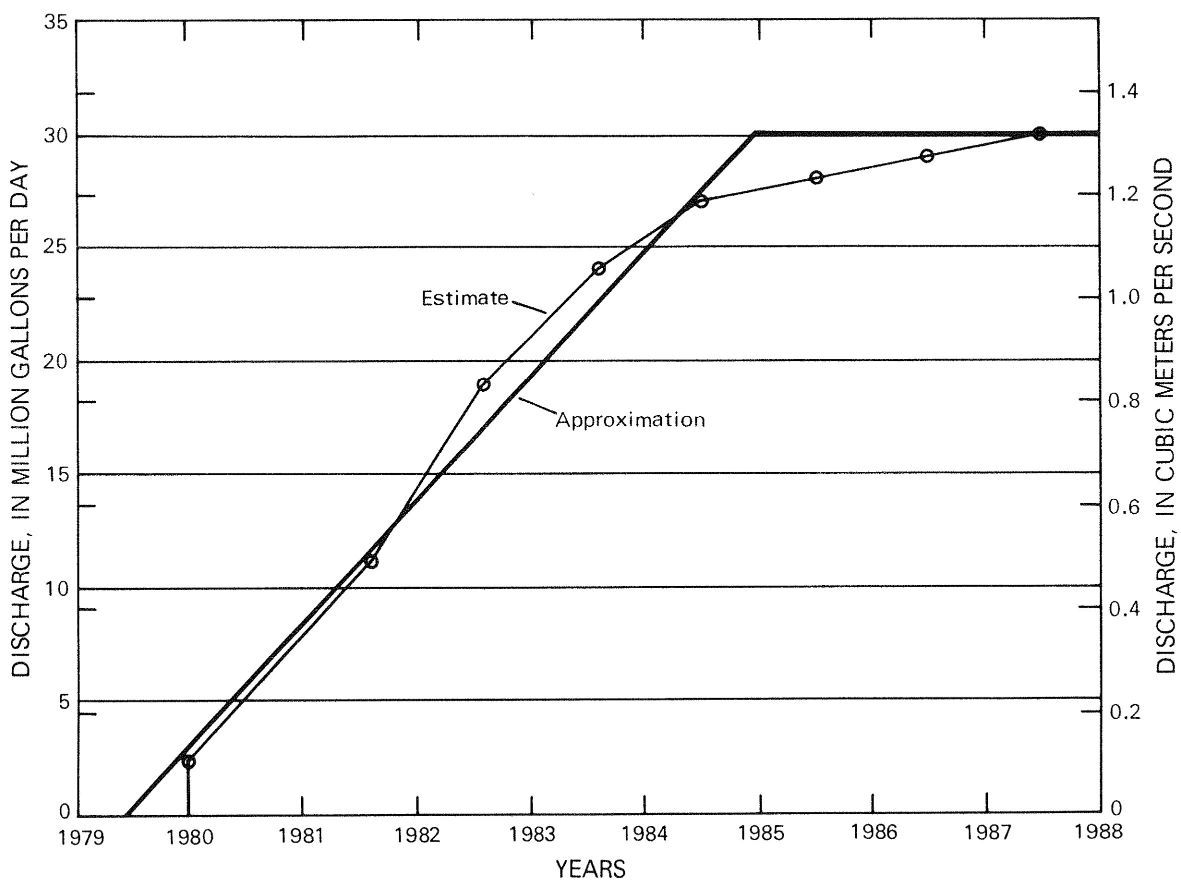



Figure 8.--Amount of effluent discharge resulting from sewerage in the Southwest Sewer District.

withdrawals in each subdistrict and was increased at the rate shown in figure 8, whereas SDD-3 contained nine subdistricts, each stressed instantaneously; (3) in SDD-3, stress began in 1974 and sewerage was completed by 1985, whereas in SWSD, stress did not begin until 1980. Because both districts are scheduled to be completed by 1985, the model stress from 1985 to 1995 was constant in both areas.

## Model Results

Predicted effects of sewerage on the water table and heads in the Magothy aquifer in SWSD alone, and as modified by sewerage in SDD-3, are shown in figure 9. Sewerage in SWSD alone lowered the water table by as much as 1.5 m (5 ft) for an area of about 7 $km^2$ (2.7 $mi^2$) in the heavily populated western part of the Suffolk sewer district (fig. 9B). The water table declined as much as 0.5 m (1 to 2 ft) as far north as the center of the island and just west of the Nassau-Suffolk County line.

Head in the Magothy aquifer declined as much as 1 m (3 ft) as a result of sewerage in SWSD alone after 20 years (fig. 9A). Magothy water levels were affected less than the water table because the Gardiners Clay restricts the hydraulic connection between the Magothy and the upper glacial aquifers in the SWSD area. Because no increase in pumpage from the Magothy was modeled, the stress in that aquifer resulted from decreased recharge that occurred north of the modeled limit of the Gardiners Clay (Getzen, 1975).

The combined sewerage in SWSD and SDD-3 lowered the water table in east-central Nassau County by as much as 6 m (20 ft) (fig. 9D) and in western Suffolk County by as much as 3 m (10 ft) by 1995. The combined sewerage did not lower the water table in the eastern part of SWSD by 1995 any more than the sewerage for SWSD alone.

The combined sewerage caused a maximum head decline of little more than 5 m (16 ft) in the Magothy aquifer (fig. 9C). Most of the decline was in Nassau County, but declines of up to 3 meters (10 ft) occurred in the eastern part of SWSD.

The rate of water-level decline was most rapid in the early part of the stress period (fig. 10). The model showed that, except in the Magothy aquifer in the combined sewer program, most of the decline would occur before 1985. After 1985, the area influenced by sewerage increased, but this increase slowed after 1995. After 1985, changes in water levels in the upper glacial aquifer due to sewerage in the SWSD were generally very small. With the combined sewerage program, most of the decline in the Magothy and water-table aquifers had taken place by 1995.

Changes in head in the Magothy may be greater than those predicted by the model because the tests were designed to indicate changes due to sewerage only. Factors that were not simulated, such as increased pumpage from the Magothy, or continued response to past pumping, may increase the declines.

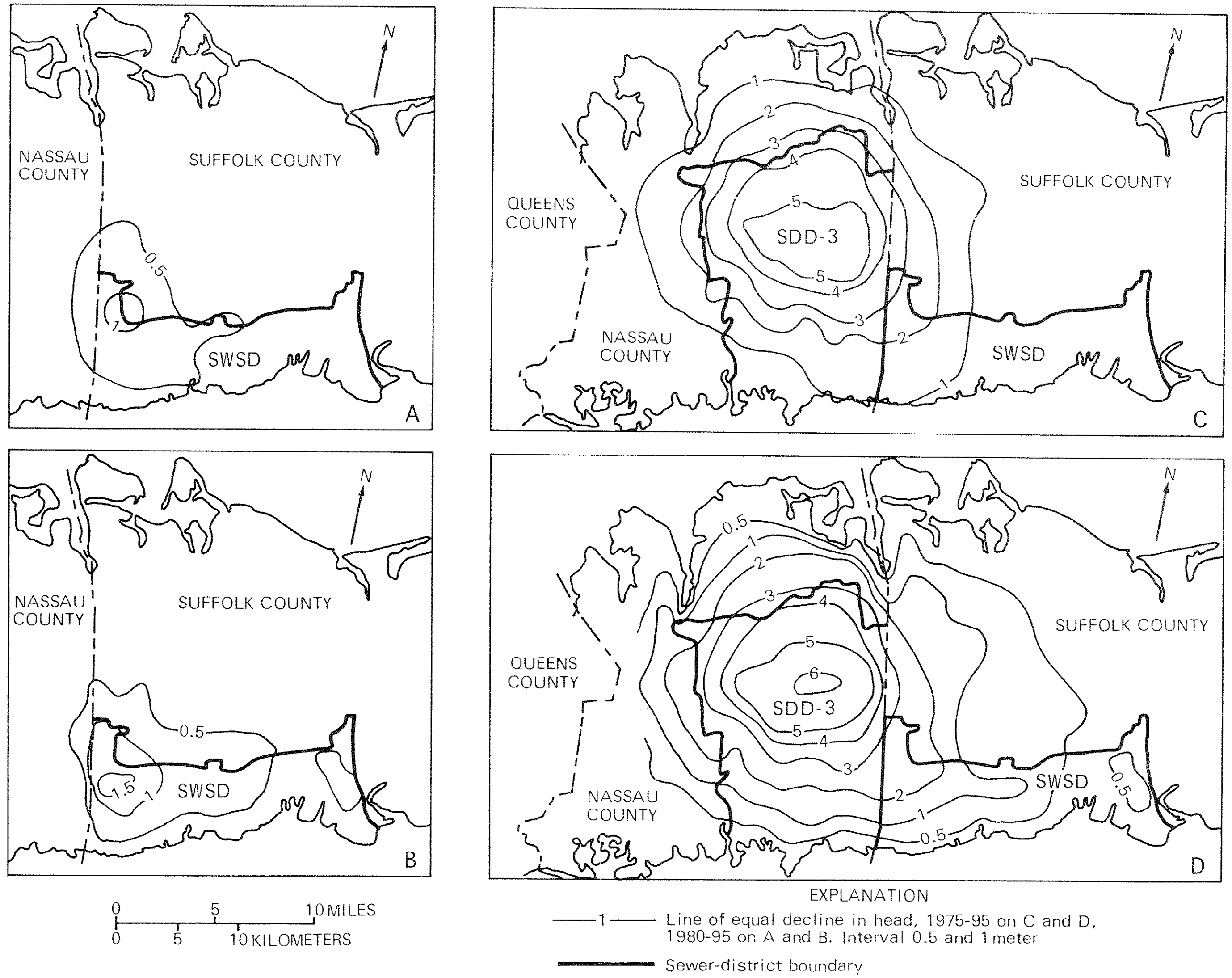



Figure 9.--Predicted head decline (A) in Magothy aquifer with sewerage in Southwest Sewer District (SWSD) only, (B) in water table with sewerage in SWSD only, (C) in Magothy aquifer with sewerage in both SWSD and Sewage Disposal District 3 (SDD-3), and (D) in water table with sewerage in both SWSD and SDD-3.

Decreases in streamflow were predicted for SWSD alone and for the combined sewered area; these are graphed in figure 11. Decreases in streamflow of less than 10 percent were not included in the computation for figure 11. The most westerly creek with greater than 10-percent decrease in flow was Massapequa Creek (G in fig. 2), about 2 mi (3 km) west of the Nassau-Suffolk County line, and the most easterly creek with greater than 10-percent decrease in flow was Champlin Creek (AE in fig. 2), which is within the sewered area. Creek flows east of Champlin Creek and within the sewer district were estimated to decrease by 6 percent or less.

The decrease in streamflow by 1995 predicted for SWSD and SDD-3 combined is plotted in figure 11 (curve b) and amounts to 40 percent of the 1974 flow by 1995. All streams as far west as the Nassau-Queens County line and as far east as Champlin Creek (AE in fig. 2) were affected. In streams east of Champlin Creek, the decrease was less than 10 percent of the annual discharge and was not considered significant.

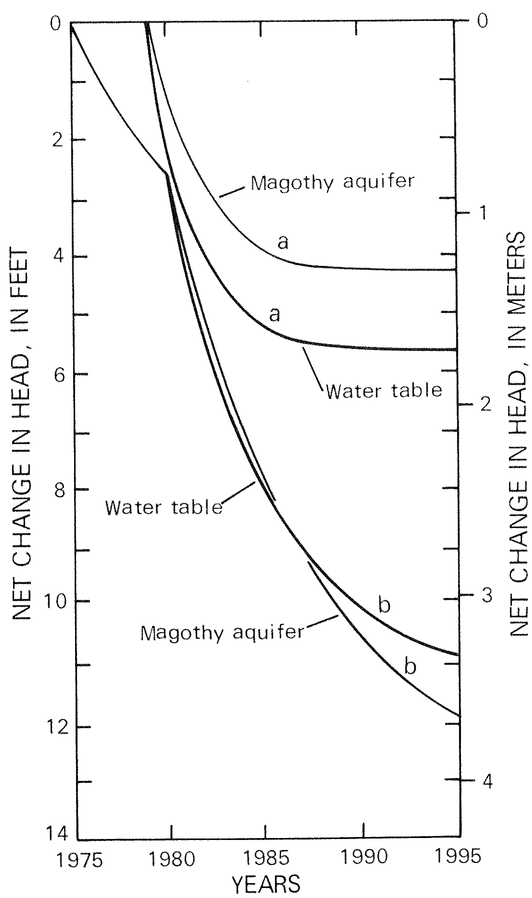



Figure 10.--Predicted rate of water-level decline in western Suffolk County resulting from sewerage in (a) Southwest Sewer District alone and (b) in combination with Nassau County Sewage Disposal District 3 during period 1975-95.

Streamflow changes shown in figure 11 differ from those in figure 7 because different areas were included in each analysis; that is, a 60-percent reduction in flow can be expected in streams from Nassau County SDD-3, whereas an overall 40-percent decrease can be expected when the two sewered areas are considered together.

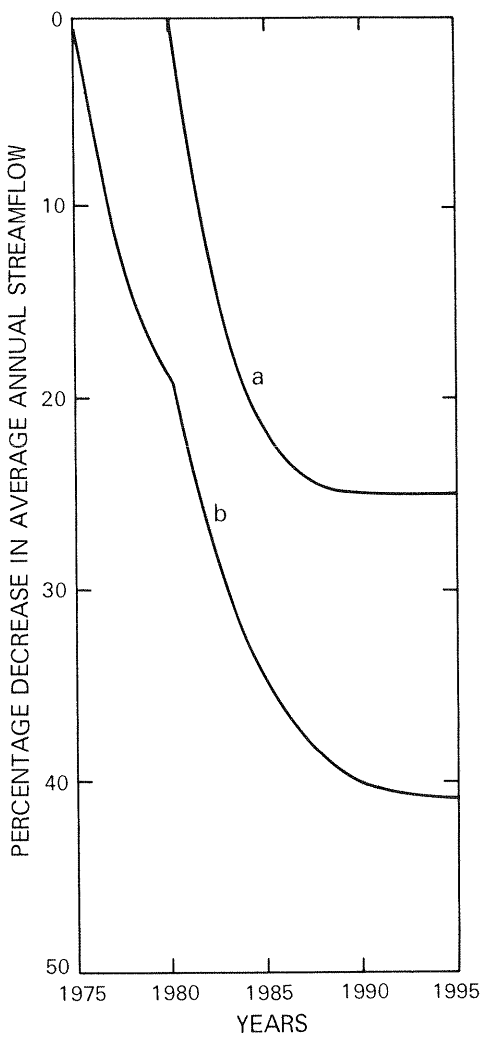



Figure 11.--Predicted decrease in average annual streamflow due to sewerage in (a) Southwest Sewer District and (b) Southwest Sewer District combined with Nassau County Sewer District 3.

## SUMMARY

Sanitary sewerage causes a loss of recharge to the ground-water reservoir on Long Island from individual domestic waste-disposal systems. For the sewer-construction program now (1976) in progress in Nassau and Suffolk Counties, a 96-Mgal/d (4.2-$m^3$/s) loss after 1985 was modeled. An electric-analog analysis of the effect of decreased recharge on ground-water levels indicated that by 1995 the water table may decline by as much as 6 m (20 ft) in east-central Nassau County and by as much as 3 m (10 ft) in western Suffolk County.

Decline in potentiometric head in the Magothy aquifer was approximately equal to declines in the water table, except in the Southwest Sewer District of Suffolk County (SWSD). This similarity is a result of the good hydraulic connection between the upper glacial and the Magothy aquifers throughout most of Nassau County. In much of the Southwest Sewer District, the Gardiners Clay, which separates the two aquifers, caused changes in the Magothy to be less than those in the upper glaical aquifer. Only in that part of Suffolk County adjacent to Nassau County did sewerage cause a widespread decline in head in the Magothy. Increased pumpage from the Magothy was not modeled, so losses in head may be greater by 1995 than predicted by the model. Increases in population and the effect of sewerage on water consumption significantly increase withdrawals from the Magothy in SWSD and may cause declines in head greater than those predicted.

The model analysis of the two sewer districts combined indicated that by 1995 streamflow could decrease to 40 percent of the 1975 long-term average annual flow. This reduction in flow would result from declines in the water table and the consequent loss of inflow to the largely ground-water-fed streams.

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